THE COASTLINE OF FORTALEZA CITY. A PRODUCT OF ENVIRONMENTAL IMPACTS CAUSED BY THE MUCURIPE HARBOR

A costa de Fortaleza. Um produto de impactos ambientais causados pela implantação do Porto do Mucuripe

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RESUMO

A avaliação dos conflitos costeiros gerados pelas etapas sucessivas de implantação de um porto ao longo da costa de Fortaleza, Estado do Ceará, no século passado, constitui o objetivo principal deste trabalho, com as seguintes constatações: a distribuição espacial das instalações e a escolha do local foram feitas sem se levar em conta a dinâmica costeira; a própria utilização do porto determinou erosão da costa, com rápida degradação do sistema por assoreamento; como os benefícios a serem gerados pelo porto foram prioritários para os planejadores, as soluções foram dirigidas para otimizar sua exploração, ignorando-se os impactos de natureza litorânea; as ações tomadas para minimizar o impacto da implantação contribuíram para modificar a costa, com o virtual desaparecimento de alguns trechos da praia; a descoberta de novas formas de uso da zona costeira, e.g. o turismo, com importância relativamente maior que a vocação original de comércio, deu origem a uma nova mentalidade no processo de administração da região litorânea de Fortaleza.

***Palavras-chaves**: zona costeira, impacto ambiental, porto de Fortaleza.*

ABSTRACT

The coastal conflicts originated by the successive implementations of a harbor along the Fortaleza coast (NE Brazil) during the last century are illustrated in this paper. Because all the designed layouts and the different locations selected for the harbor were done without considering the local coastal dynamics, the use itself entailed port shoaling and the system was rapidly degraded with coastal erosion. Since the economical benefits generated with the port was a priority for planners, solutions were mainly designed to optimize port exploitation without paying attention to the coastal response. The interest in mitigating the resource degradation appeared with the occurrence of extensive coastal damages and the nearly full disappearance of the beach in some stretches. Moreover, the appearance of a new coastal use, i.e. tourism, with a potential economic importance higher than the previous one, i.e .trading, has originated a growing awareness in coastal zone management in the Fortaleza's "coastal" way of thinking.

***Key words**: coastal zone, environmental impact, Mucuripe harbor.*

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INTRODUCTION

The implementation of an effective coastal zone management policy involves the search for an equilibrium between coastal uses and resources. This is because, in general, any such policy entails the use of a resource that may be non-renewable (Sorensen & McCreary, 1990). However, in many cases coastal management is not the product of a pre-determined policy but the result of a chain of actions on the coastal zone without consideration for the total syste (Garcia, 1996). In such cases, one cannot properly speak of coastal management but coastal use. Under this scenario, the interest in achieving an appropriate balance between the use and the resource will only appear when the latter begins to be consumed in such a way that other uses or even, other resources, are influenced.

This pessimistic view is not a rare case since many examples can easily be identified around the world. However, in some cases, they are the result of the implantation of a use during a period in which the concept of coastal management was uncommon, and that use was essential for the development of the respective zone.

In what follows we shall illustrate how one coastal use implemented more than one century ago has determined the evolution of a certain resource, restricting the appearance of new uses, until the resource is artificially restored. The case selected corresponds to the effects of a port development in Fortaleza City, Ceará State, Brazil. The implementation of such a use (port) in the area of study resulted in a continuous alteration of the resource (coastal fringe) as expected, but due to the local characteristics, also a continuous alteration of the use itself. Thus, the port had to be moved several times because the dominant coastal dynamics along Fortaleza induced its siltation making it non-operational. In all cases, the successive attempts to solve the problem were thought only on a portuary basis, and they attempted to solve the effects of the problem rather than the origin.

Studied Area

Fortaleza City is located on Ceará State' coast (figure 1), which is about 573 km wide and it is mainly consisted of long sandy beaches, interrupted only by small river mouths and rocky headlands determining changes in the coastal orientation.

The main geomorphological feature is the former Mucuripe Cape (presently, Mucuripe harbor), a rocky headland splitting the coastline in two stretches with different orientations. Moreover, in the southeast part of the area large dune fields reach heights of up to 50 m.

The rivers have been classified as estuaries with salt wedge for the largest river flows, and well mixed estuaries during the dry season, without any significant sediment supply (Freire & Maia, 1991; Maia et al., 1994). The area is a mesotidal environment, with a diurnal tide which has a maximum range of 3 m.

The local wave climate can be roughly described by an averaged significant wave height, Hs, of 1 m, a mean period, Tz, of 5 sec and a full dominance of the eastern waves (see Figure 1). The wave characteristics and the coastal orientation determine a large angle between waves and coastline, which potentially induces high longshore transport rates.

Historical Background

The first attempt to create a port at Fortaleza City was around the beginning of the 19th Century. It was due to the interest of local authorities to promote and improve the commercial activities in the zone. Thus, the first port facilities were built in 1807, consisting of a wooden pier, which was rapidly replaced by a larger one equipped with a crane (figure 2). These first installations, although very simple and with limited dimensions, began to alter the littoral dynamics and they were rapidly disabled due to the induced sediment deposition which produced the port siltation.

At that time (1825) the local bathimetry along Fortaleza City was characterized by the presence of two large sand banks (figure 3). A further survey (1832) indicated that the local depth features remained similar, despite their showing some deepening at Mucuripe Cape, and shallowing waters eastwards. Apart from the lack of accuracy, these data characterize the area as a zone with a large sediment supply and with a net longshore sediment transport directed westwards.

Options to select a new, definitive port location were investigated. The original idea was to take advantage of the existing geomorphology to look for a sheltered zone and, at the same time, to prevent siltation. In 1875 it was decided that the new port should be built around the reefs in the center of the be. This new project was finalized in 1886 and it consisted of a rocky, 670 m long breakwater built on the reefs. It had two alignments, the first one, 480m long, following the reef line, parallel with the coastline, and the second one, about 190 m long, following a E-W direction (Joppert, 1936). During its construction, two important problems rapidly appeared: the formation of a very large bar upstream of the breakwater, and the nearly overall siltation of the sheltered area.

In 1899, the coastline had advanced about 150 m along the breakwater and port facilities were no longer useful. To solve the problem, different works were planned to block the sediment transport along the coast and stop the sediment accumulation in the port. The coastal dunes were fixed and several jetties were built upstream of the port, but the problem persisted.

A new port configuration and location (the third) was then selected and a pier was newly built using steel piles, around 1920-1926. However, like the previous attempts, the installations were rapidly siltated and ships with a draught larger than 4 m could not use it. Afterwards, new projects were presented to the local authorities to solve the question of where and how to design a port for Fortaleza, but owing to technical and financial problems no action was taken until 1930, when the present port location was selected, at the Mucuripe Cape..

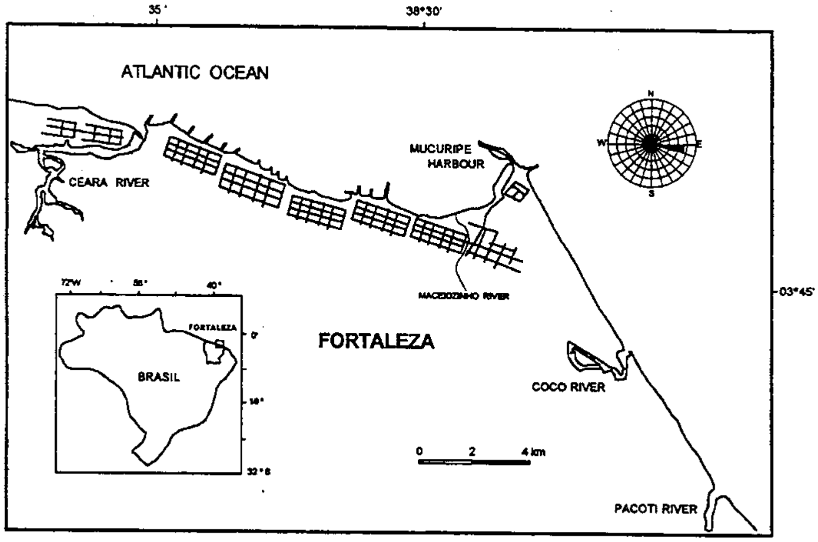

Figure 1 –Map of Fortaleza City's coast line and wave directional distribution.

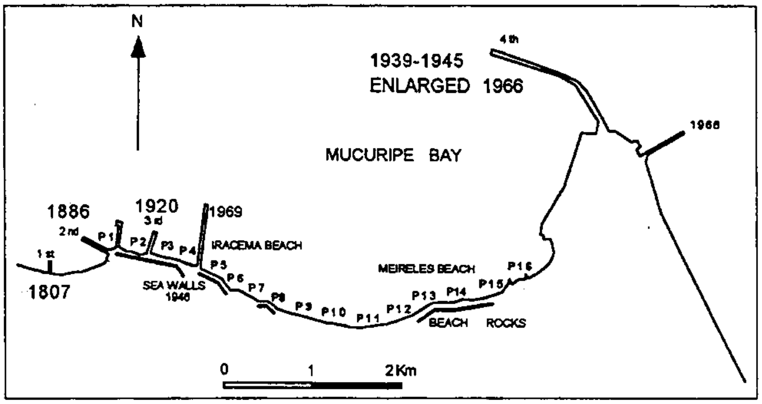

Figure 2 – Map of Mucuripe embayment, showing the different port construction and profile locations.

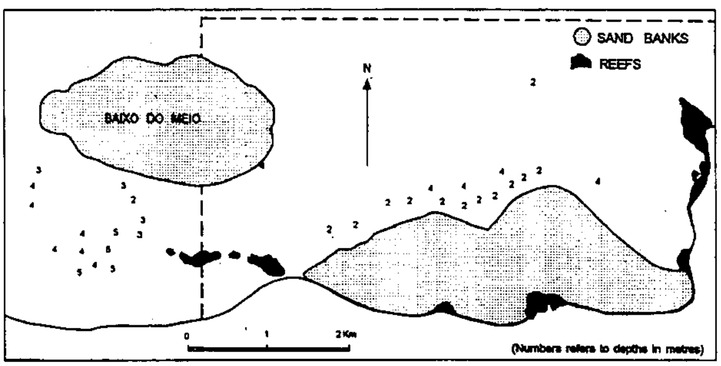

Figure 3 – Bathymetry of the Fortaleza coast in 1825 (adapted from Morais, 1980). Dashed rectangle corresponds to Figure 2.

Current Situation

The new port at Mucuripe Cape was composed by a main, 1,400 m long breakwater, with a 10 m depth at its tip (figure 2). The construction spanned the period 1939-1945 during which three problems arose simultaneously: (i) the breakwater was rapidly "filled" by sand, (ii) the port did not correctly shelter the area from eastern waves and (iii) beaches downstream from the port began to be eroded.

The main difference with respect to the previous situation was that then the influence of the port was of a local nature owing to the dimensions of the facilities and the location. However, with the port site selected, a new boundary condition for the studied coastal stretch was introduced. In natural conditions, i.e. without the port, there was a continuous sediment feeding from the eastern part towards the west around the headland. However, the construction of the port began to interrupt the longshore sediment transport, acting as a barrier for it.

Figure 4 shows the sediment blocking effect of the breakwater during its construction. At the beginning, the bathymetry was relatively parallel with the coast. As the breakwater was enlarged, the sediment was blocked and the shoreline advanced along the dike causing the sediments to bypass the breakwater, forming a spit-shaped sand banks at its tip. This behavior, typical of ports located in longshore sediment transport-dominated coasts (Wiegel, 1964), indicated that the sediment supply to the newly-formed Mucuripe Sound beach had been cut off.

To analyze the changes induced along Fortaleza City's coastline after the definite selection of the port location, 16 control points with a spacing of about 200 m along the coast were selected (figure 2). Taking the coastline of the year 1929 as representative of the reference situation before and just after the port construction (1947), a generalized large erosion is observed along the entire studied coastline (figure 5). The mean coastal recession for this period is about 77 m, being Iracema Beach, with a maximum value of 130 m (the most affected zone), where several buildings and facilities were damaged because of seaside erosion. The lowest recession, about 30 m, was found at Meireles Beach. This large difference in shoreline behavior was caused by the presence of natural obstacles such as beach rocks.

The interaction between the port and the existing littoral dynamics altered the natural sediment path along the coast, and large amounts of sediment were deviated to deep waters from the tip of the breakwater, forming a linear sand bank parallel with the coastline at a depth of about 10 m (original depth at the breakwater tip). The continuous growth of this bank as well as its behavior (some migration was observed) altered the functioning of the harbor installations because the port approach channel was siltated by sand bank movements.

The appearance of silt as well as problems associated with coastal erosion induced a new study to solve both questions. Simultaneously, several seawalls were built in the most eroded zones to reduce or control the coastal recession. The study was performed on a physical model (Sogreah, 1957) and the proposed solution consisted of the enlargement of the main breakwater and the construction of an additional jetty eastwards of it to block the sediment by-pass. These works were finalized at 1963.

Comaparing the current situation in 1964 with the previous one (1947), it can be seen that the coastal recession had a decrease, reaching a mean erosion of 21m, which was partly due to the implementation of the above-mentioned coastal protection works. However, in non-protected areas such as Iracema Beach, the coastal recession was significantly greater, reaching a value of about 56m.

Apart from this erosive behavior, sediments began to be deposited in the sheltered area created at the leeside of the breakwater, generating siltation problems and local shoreline advance. This sediment deposition was produced by local currents induced by the diffraction of dominant eastern waves at the port breakwater, a mechanism that is poorly documented (Lepetit, 1976).

This wave diffraction induced current can be used to explain the migration of the Maceiozinho stream mouth (figure 1) from west to east, but it can be also the result of sediment retention by the port, according to Morais & Pitombeira (1974).

From the point of view of economic exploitation, the breakwater enlargement as well as the building of the eastern jetty improved the situation, although periodical dredging was necessary. However, regarding the coastal stability, the erosive situation persisted and the building of a new jetty at the Iracema Beach was required in order to reduce coastal erosion.

During the period from 1964 to 1980, the coastline continued to be eroded, though at a lower magnitude, with a mean recession of 11 m (figure 5), what can be ascribed partly to the protective works and partly to the fact that in some places the coastline reached the limit conditions, that is total disappearance of the subaerial beach. The accretion observed at the western part of the coast (points 3 and 4) was due to the construction of the jetty at Iracema Beach around the year 1969.

Because the problem was induced by the interruption of the longshore sediment transport, the selected coastal protection works only solved it from a local point of view but at the same time, they propagated the problem downwards. This kind of solution brought about a new situation, namely the western city waterfront is being protected by about 13 jetties and the erosion is now taking place at the western neighboring Caucaia county.

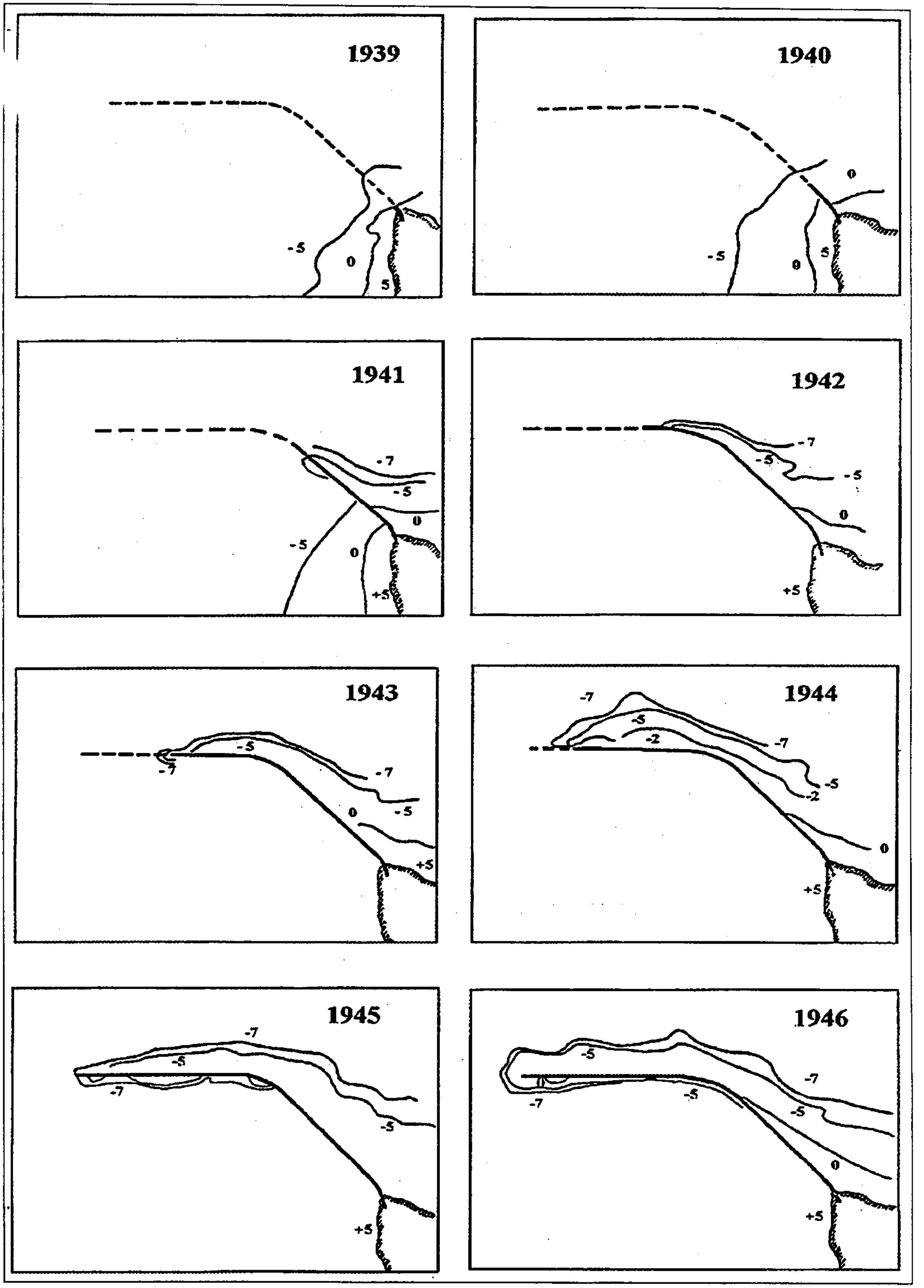

Figure 4 – Bathymetric changes during the construction of the main breakwater of the Mucuripe harbor.

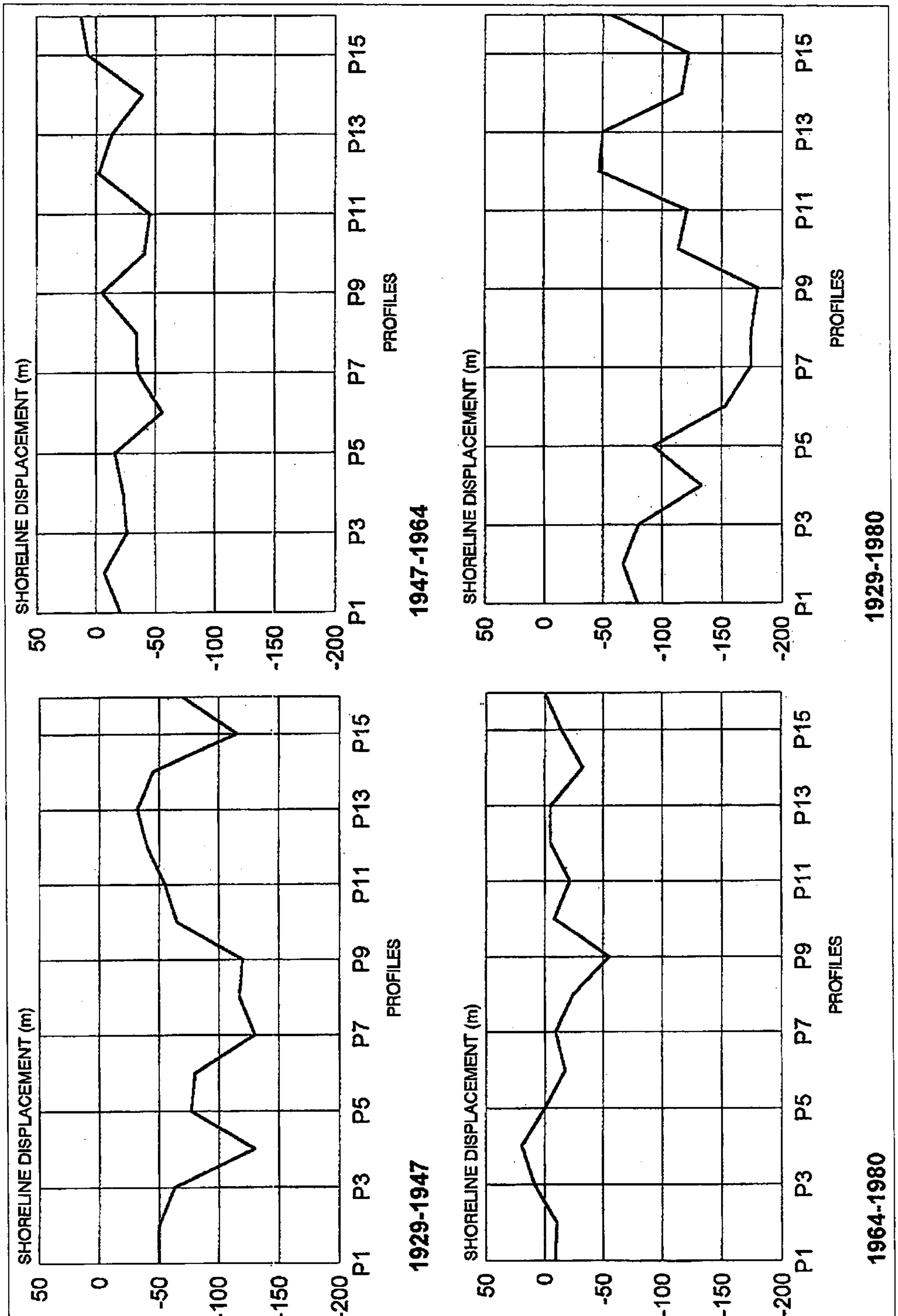

Figure 5 – Shoreline rates of change along the Mucuripe embayment.

DISCUSSION

The historical changes of the coastline of Fortaleza ... are intrinsically linked to the port development, as they are fully controlled by the net longshore sediment transport pattern. At former periods, this coastal stretch was characterized by a large sediment supply from the eastern coast. When the first port installations were placed on Iracema Beach, they were continuously siltated, thus preventing their correct exploitation, but without inducing significant erosion problems.

At that time, the only interest was to obtain a functional port to promote commercial activities as well as to improve the city's maritime connections. The coastal management (if any) can be considered as portuary-use-oriented and all the efforts were devoted to this objective. Local coastal modifications were considered only in as much as they interfered with the port exploitation. In all the cases, the different choices for port location before the present one were badly exercised because in all of them siltation appeared instantaneously. The bestA port location was selected only from the portuary point of view, without considering the possible coastal modifications.

The selected port location at Mucuripe Cape changed the sedimentary balance because it acted as a barrier to the net longshore sediment transport and, at the same time, part of the sediment was deviated to relatively deep waters. With the port construction, the westward coast began to be eroded severely and at the same time, the port installations continued being siltated. This situation introduced a new element in the local "coastal way of thinking" in the sense that under this scenario two problems had to be solved, port functionality and coastal erosion. Coastal erosion became a problem because it began to produce losses in the city infrastructure (roads and buildings were damaged) and then some protective works had to be implemented. The selected coastal protection measures, building of hard structures where severe erosion took place, were designed to solve the effects and not the origin of the problem (sedimentary deficit due to the blocking effect of the port). At this moment, the management is still port-oriented, although a small part of this management effort has to be devoted to protecting the coast.

The next step was again primarily directed to optimizing the port facilities because due to the location selected, the port continued being siltated. The solution adopted was to block the sediment by constructing a shore-perpendicular jetty, but coastal erosion problems persisted because a more effective sediment blocking was achieved.

Moreover, due to the dominant eastwards wave system and port orientation, wave diffraction induced currents directed towards the sheltered port installations. The siltation continued although in this case related to these currents and not to the bypass of sediment from the eastern coast. This problem was solved in a specific manner by periodical dredging of harbour facilities.

Additional protection measures were taken, but as in previous cases, the solution was directed towards the effects ratter than to the causes of the problem, that is the building of 13 jetties on the waterfront did not prevent erosion, but rather made it to propagate westwards..

This situation, common on many other coasts worldwide, is the result of a lack of integrated management of the coastal zone which could be taken as normal in earlier times, when the coast was not considered as a resource in itself but only as a door to trade and urban communication. However, as described throughout in this paper, because the interaction between use and resource was not considered, the use was inefficient since the original purpose (portuary service) was not achieved at any moment due to siltation problems.

This approach to the solution of coastal erosion extends its magnitude, because it is propagated along the coast, affecting larger beach stretches. Only when the coastal zone was seen as na economic resource to be conserved, as a consequence of the appearance of a new use demanding such resource to be developed as e.g. the tourism, did a real interest on coastal planning begin.

The final situation bearing severe constraints for the effective implementation of a new use requiring the same resource which is by now almost consumed or, at least, deteriorated, is due to the fact that any coastal use implies the utilization of a coastal resource (Vallega, 1996) and, in many cases, when the economical benefits generated (or expectation of them) are a priority for planners, little attention is paid to the resource consumption. Even in the case of a decreasing resource (coastal erosion), the interest in reversing or stopping the process only appears when a new coastal use, requiring the same resource, begins to be implemented.

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